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April 25, 2018
File No. 129687-010

Ms. Maribeth Greenslade
Project Manager
Arizona Department of Environmental Quality
1110 West Washington Street
Phoenix, Arizona 85007

**Re: Draft Proposed Procedures for Determining Alert Levels and Aquifer Quality Limits
for Groundwater Compliance Monitoring
Aquifer Protection Permit No. P-106360**

Dear Ms. Greenslade:

Pursuant to our conversation on March 26, 2018, Florence Copper Inc. (Florence Copper) has prepared the attached *DRAFT Proposed Procedures for Determining Alert Levels and Aquifer Quality Limits for Groundwater Compliance Monitoring* for review by the Arizona Department of Environmental Quality. This memo presents a proposed method for establishing Alert Levels and Aquifer Quality Limits in cases where the standard methodology may provide sufficient protection against false positive indications.

This proposal is being submitted as a draft for discussion purposes. Florence Copper looks forward to the opportunity to discuss the contents of this memo with you and we value your input regarding the proposed methods. We will contact you to set up a time to discuss the memo once you have had a chance to review it. Following that discussion, we will prepare and submit a revised and finalized proposal that reflects your input.

Please contact me at 520-374-3984 if you require any additional information.

Sincerely,
Florence Copper Inc.

A handwritten signature in blue ink, appearing to read 'Daniel Johnson', is written over a horizontal line.

Daniel Johnson
Vice President – General Manager

Attachment:

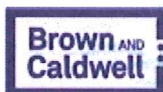
Draft Proposed Procedures for Determining Alert Levels and Aquifer Quality Limits for Groundwater Compliance Monitoring

Proposed Procedures for Determining Alert Levels and Aquifer Quality Limits for Groundwater Compliance Monitoring

Florence Copper Project
Florence, Arizona

April 25, 2018

DRAFT



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Phoenix, Arizona 85004

INTRODUCTION

Temporary APP No. P-106360 requires the calculation of alert levels (ALs) and aquifer quality limits (AQLs) for groundwater compliance monitoring at the Florence Copper Inc. facility (Facility).

The permit outlines methodology for calculating ALs, along with a set of criteria to follow for selecting the final AL and AQL in Permit Conditions 2.5.3.2.1 – Alert Levels for POC Wells, and 2.5.8.5.1 – Alert Levels for Supplemental Wells and MW-01. Based on preliminary evaluation of the data, the majority of the ALs can be set using the permit-described methodology. In cases where datasets have reduced variability, this document outlines proposed modifications to the permit method.

Please note that some example datasets are provided for the purposes of demonstration and are not considered to be complete or final.

PERMIT METHODOLOGY

The Temporary Aquifer Protection Permit (APP) outlines the methodology for setting ALs and AQL. There are three general steps:

- Data preparation;
- Using the mean and standard deviation to calculate a statistical AL; and
- Using case criteria to determine the final ALs and AQLs.

DATA PREPARATION

Permit Methodology

Data will be prepared for AL calculations as outlined in the Temporary APP.

- ALs will be calculated using a minimum of 8 and a maximum of 12 consecutive sample rounds.
 - In the majority of cases, 9 sample results will be used; except where an outlier is identified.
- Any data where the laboratory practical quantitation limit (PQL) exceeds 80% of the AWQS will be excluded from the calculations.
- Obvious outliers will be excluded from the calculations.
 - Outliers will be determined primarily on the basis of graphical review.

In addition, it is proposed that:

- Duplicate analytical results will be removed.

Handling of Non-Detect Values

The APP prescribes using a value of one-half of the PQL for results below the detection limit for the calculation of ALs. This is used where greater than 50% of the results are non-detect.

For cases where a dataset contains at least one non-detect but less than 50% of the results are non-detect, the statistical method proposed below accommodates the non-detects, which only need to be identified at the value of the PQL.

ALERT LEVEL CALCULATIONS

Permit Methodology

The permit prescribes calculation of the ALs based on a tolerance interval. The AL is calculated with the following equation:

$$AL = \bar{x} + k \cdot s$$

where:

\bar{x} = the mean of the existing concentrations in a given well;

s = the standard deviation of the existing concentrations in a given well; and

k = a multiplicative factor that accounts for uncertainty in the analysis and the desired coverage and confidence of the AL (discussed below)

The values of \bar{x} and s are calculated from the existing concentrations using appropriate statistical methods.

Development of the k Constant

The permit recommends using the Lieberman Tables for a one-side normal tolerance interval with a 95% confidence level. Based on a 99% coverage and a sample size of 9, the k value for this data set would be 4.143.

In reviewing preliminary calculations, it was observed that many of the datasets have low-variability, resulting in ALs that only marginally exceed the maximum observed value. Table 1A – Example Case 1 shows the calculation of the AL for a magnesium dataset with no non-detect values:

Average – 9.0

Maximum – 11

Standard Deviation – 1.2

Calculated UPL = $9.0 + 1.2 * 4.143 = 14$

Because the AL is only marginally higher than the maximum observed value, it is likely that a result may exceed the calculated AL due to natural water quality variation. The 99% coverage of the AL means that the AL represents the 99th percentile of the dataset, which would be exceeded approximately 1% of the time even under natural conditions. Based on the number of wells and analysis required for the project, this could translate to as many as 10 false positives in a year.

Modified k Value – Upper Prediction Limit

An alternative statistical method for calculating the k value is described by the United States Environmental Protection Agency (EPA) in “Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance” (EPA, 2009). The AL calculated is an Upper Prediction Limit (UPL), representing a value that is unlikely to be exceeded by any single future measurement, unless groundwater conditions have changed. The value of k is calculated as:

$$k = t_{1-\alpha, n-1} \cdot \sqrt{1 + \frac{1}{n}}$$

where:

n = the sample size of the existing concentration dataset for a given well;

α = the desired false positive rate of the UPL (discussed below); and

$t_{1-\alpha, n-1}$ = the value of the t-distribution for the given values of n and α

Because the dataset of existing concentrations represents only a sample of the full range of possible concentrations, the chance that the UPL will be exceeded even in the absence of a release to groundwater cannot be reduced to zero. The chance that the UPL will be exceeded in the absence of a release to groundwater is managed through the chosen value for α .

An exceedance of a UPL even in the absence of a release to groundwater is called a “false positive.” The expected rate of occurrence of false positives (i.e., the false positive rate) is controlled through the value of α . α is equal to the desired false positive rate, and thus a value of $\alpha = 0.01$ would indicate that the UPL has a 1% chance of being exceeded every time a new sample is collected, even if a release to groundwater has not occurred.

Future groundwater samples will be compared to ALs and AQLs for many parameters in many wells multiple times per year. Even if every UPL had only a 1% chance of recording a false positive during each comparison to a new data point, the chance of observing at least one false positive throughout the year would be unacceptably high. To avoid this problem, the false positive rate of each UPL is set at a sufficiently small value to ensure that the overall false positive rate over the course of the year (called the cumulative false positive rate) is reasonably small.

The value of α for each UPL is determined from the desired cumulative false positive rate using the following equation (EPA, 2009):

$$\alpha = 1 - (1 - \alpha_c)^{1/N_T}$$

where:

α_c = the desired cumulative false positive rate; and

N_T = the number of tests (i.e., comparisons to a UPL) conducted over the course of a year.

The number of comparisons to a UPL per year is determined from the number of parameters, number of wells, and sampling frequency. For this APP, four parameters (the common ions) are

sampled four times per year. A full set of parameters (27 parameters in total) is sampled twice per year. The number of wells that are to be sampled each year include the 3 new POC wells, 9 supplemental wells plus 4 existing POC wells that already have established ALs and AQLs. Thus, the total number of comparisons per year is 992.

The cumulative false positive rate is chosen to minimize, to the degree possible, the chances of observing at least one false positive in a given year. The trade-off to choosing a low cumulative false positive rate is that the value of k , and thus the UPLs, increase and are less sensitive to detecting releases to groundwater. However, given the nature of the mining solutions, a release to groundwater would be expected to produce a significant change in groundwater chemistry, quickly exceeding the ALs. Thus, minimizing false positives can be achieved without limiting the effectiveness of the groundwater monitoring program.

The value of the cumulative false positive rate selected in this analysis is 0.01. This means that there will approximately a 1% chance of observing at least one false positive every year, provided that groundwater conditions do not change (either due to a release or through natural variation). In other words, false positives will be expected to occur with a frequency of one every 100 years, assuming stable groundwater conditions.

The cumulative false positive rate of 0.01 gives a value of α for each UPL of 1.01×10^{-5} , which gives a value for k of 9.37 when the sample size of the dataset is 9. Although the k value would be higher for any data set with 8 samples, where an outlier is excluded, the same k value of 9.37 will be used for consistency, since this is a more conservative result.

Using this proposed k value for the example case yields a UPL that is less likely to have false positives but is nonetheless protective of groundwater.

For Example Case 1:

Average – 9.0

Maximum – 11

Standard Deviation – 1.2

Calculated UPL = $9.0 + 1.2 * 9.37 = 20$

Adjusted Standard Deviation

In some cases, the datasets have extremely low variability. This is not unexpected because the data were collected over a relatively short period of time and may not reflect long-term variability in groundwater conditions. Table 1B – Example Case 2 demonstrates the potential for a UPL, using the revised k value, that is still likely to result in false positives:

Average – 23.3

Maximum – 24

Standard Deviation – 0.5

Calculated UPL = $23.3 + 0.5 * 9.37 = 28$

A water-quality variation of less than 15% would yield an exceedance.

To account for the low variability, it is proposed to adjust the standard deviation:

- The coefficient of variation (CV) will be calculated for each dataset. The CV, which is equal to the standard deviation divided by the mean, is a standardized measure of variability. In other words, the CV for a dataset with a mean of 1,000 can be directly compared with the CV for a dataset with a mean of 10. The same cannot be said for the standard deviation, which is dependent on the magnitude of the data points as well as the variability.
- For datasets with a CV less than 0.1, the standard deviation will be set to 10% of the mean.

For Example Case 2:

Average – 23.3

Maximum – 24

Standard Deviation – 0.5

Coefficient of Variation = 0.02, below 0.1

Adjusted Standard Deviation = 10% of Average = 2.3

Calculated UPL = $23.3 + 2.3 * 9.37 = 45$

This yields a UPL that is similar in relative magnitude to the dataset as Example Case 1 and less prone to false positives.

Datasets with Non-Detects

For datasets with all detected results, the mean and standard deviation are calculated using standard methods (e.g., arithmetic average and sample standard deviation formulas found in software such as Microsoft Excel).

If a dataset contains at least one non-detect but the percentage of non-detects is less than 50%, it is proposed to calculate the mean and standard deviation using the Kaplan-Meier Method, as recommended by Helsel (2005). All calculations will be performed in Microsoft Excel, the R Statistical Programming Language (R Core Team, 2016), or the EPA's ProUCL software, version 5.1 (EPA, 2015).

For datasets with 50% or more non-detects, it is proposed to use the permit-described method, substituting non-detect values with one half the value of the PQL to calculate the average and standard deviation of the dataset. If appropriate, an adjusted standard deviation of 10% of the mean would be used.

For datasets with 100% non-detects, it is proposed to use an average of the PQLs and an adjusted standard deviation of 10% of the mean.

Examples of the three types of non-detect datasets are shown in Table 1C – Example Case 3. While these last two approaches are not ideal, they at least provide estimates for UPLs for comparison to a standard, or provide a UPL where no standard exists. Parameters with large numbers of non-detects include certain trace metals, organics, and radium.

UPLs by Well vs by Parameter

Four parameters have been selected in the Temporary APP as primary indicator parameters. Individual UPLs will be calculated for these on a well-by-well basis.

For metals, organics, and radiochemicals where there is limited variability and large number of non-detects, it is proposed to use the highest UPL calculated for the 12 wells in order to have a standardized AL. However, in the event that a well is significantly different from the other wells, a standard UPL will be set for the main group of wells and a separate UPL for the well(s) with unique results. For example, many total radium values are non-detect; however, two wells have exhibited total radium values above the Aquifer Water Quality Standard (AWQS). In this case, the highest UPL calculated for the first ten wells would be used for those wells, and then a separate UPL calculated for each of the remaining two wells which have values above the AWQS.

ALS AND AQLS FOR PARAMETERS WITH AWQS

Once a UPL has been calculated, it will be compared to the numerical AWQS to determine the final AL and AQL in accordance with the permit. Table 2 outlines the case criteria described in the permit. Table 3 gives a summary of what method will most likely be used to set the final AL for each parameter; however, this is based on preliminary data and subject to change.

Permit Methodology

Numerical AWQS have been established for fluoride, eleven (11) trace metals, benzene, toluene, ethylbenzene, xylene (BTEX), alpha, and radium. For each parameter with an AWQS, the ALs and AQLs will be set as follows:

Case 1 – POC Wells

- If greater than 50% of the results for a well are non-detect, then the AL will be set at 80% of the AWQS and the AQL will be set equal to the AWQS;
- If the calculated UPL is less than 80% of the AWQS, then the AL will be set at 80% of the AWQS and the AQL will be set equal to the AWQS;
- If the calculated UPL is greater than 80% of the AWQS but less than the AWQS, then the AL will be set equal to the UPL and the AQL will be set equal to the AWQS; and
- If the calculated UPL is greater than the AWQS, then the AQL will be set equal to the calculated UPL, and no AL will be set for that parameter at that monitoring point.

Case 2 – Supplemental Wells

- If greater than 50% of the results for a well are non-detect, then the AL will be set at 80% of the AWQS;
- If the calculated UPL is less than 80% of the AWQS, then the AL will be set at 80% of the AWQS;
- If the calculated UPL is greater than 80% the AWQS but less than the AWQS, then the AL will be set equal to the calculated UPL value; and
- AQLs are not required for supplemental wells.

Note that nitrate has an AWQS; however, the Temporary APP states that ALs and AQLs will not be established for nitrate as it is not a parameter of concern for the process.

ALS FOR INDICATOR PARAMETERS

Indicators with Secondary Standards

Indicator parameters do not have an established AWQS. Secondary drinking water standards (SDWS) are available for sulfate, total dissolved solids (TDS), and five trace metals. For each parameter with an SDWS, it is proposed to set ALs using the same methodology described above.

- If greater than 50% of the results for a well are non-detect, then the AL will be set at 80% of the SDWS;
- If the calculated UPL is less than 80% of the SDWS, then the AL will be set at 80% of the SDWS;
- If the calculated AL is greater than 80% the SDWS, then the AL will be set equal to the calculated UPL value; and
- For the five trace metals, as the concentrations are generally low and the indicator parameters are not of primary concern for groundwater protection, the AL will be set equal to the highest AL in any well for each indicator metal.

Indicators with No Secondary Standard

Two parameters, magnesium and cobalt, do not have an AWQS or SDWS.

- The AL for magnesium will be set to the calculated UPL for each well; and
- The AL for cobalt in all wells will be set to the highest calculated UPL for any well.

AQLs are not required for parameters that do not have an established AWQS.

REFERENCES

- EPA (United States Environmental Protection Agency), 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance. Office of Resource Conservation and Recovery. EPA 530/R09-007. March.
- EPA (United States Environmental Protection Agency), 2015. ProUCL Version 5.1.00 Technical Guide – Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. October.
- Helsel, D. R., 2005. Nondetects and Data Analysis – Statistics for Censored Environmental Data. Wiley-Interscience – A John Wiley & Sons, Inc., Publication. Hoboken, NJ.
- R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

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TABLE 1A - EXAMPLE CASES DEMONSTRATING PROPOSED UPL CALCULATIONS

Example Case 1 Comparison of UPL Calculations Using the Permit <i>k</i> Factor and the Proposed UPL <i>k</i> Factor.		
Description	M57-O Magnesium	Comments
Results	11	Example Values Detected at Each Sampling Event
	7.5	
	7.6	
	10	
	9.4	
	9.0	
	9.0	
	8.6	
Number of Samples	8	
Number of Detections	8	
Number of Non-Detections	0	
Percentage of Non-Detect	0%	
Maximum Value Detected	11	
Calculation Method	Direct Calculation	
Average of Detected Values	9.0	
Standard Deviation	1.2	
Permit <i>k</i> Value	4.143	One-side Tolerance Interval, 95% Confidence
Calculated AL Using Permit <i>k</i>	13.8	Not Protective Against False Positives
Proposed <i>k</i> Value	9.37	UPL with 99% Confidence Level
Revised AL Using Proposed <i>k</i>	20	Sufficiently Protective Against False Positives

Notes:

All results in milligrams per Liter (mg/L).

UPL = Upper Prediction Limit

TABLE 1B - EXAMPLE CASES DEMONSTRATING PROPOSED UPL CALCULATIONS

Example Case 2		
Comparison of UPL Calculations Using the Traditional Standard Deviation and the Proposed Adjusted Standard Deviation		
Description	M52-UBF Magnesium	Comments
Results	24	Example Values Detected at Each Sampling Event
	23	
	23	
	23	
	23	
	24	
	23	
	23	
Number of Samples	8	
Number of Detections	8	
Number of Non-Detections	0	
Percentage of Non-Detect	0%	
Maximum Value Detected	24	
Calculation Method	Direct Calculation	
Average of Detected Values	23.3	
Proposed <i>k</i> Value	9.37	UPL with 99% Confidence Level
Standard Deviation	0.5	Traditional Standard Deviation
Calculated UPL	27.6	Not Protective Against False Positives
Coefficient of Variation	0.02	StDev/Ave Must be Greater than 0.1
Adjusted Standard Deviation	2.3	10% of Average
Revised UPL Using Adjusted Standard Deviation	45	Sufficiently Protective Against False Positives

Notes:

All results in milligrams per Liter (mg/L).

UPL = Upper Prediction Limit

TABLE 1C - EXAMPLE CASES DEMONSTRATING PROPOSED UPL CALCULATIONS

Example Case 3				
Examples of Calculations which Require Handling of Non-Detect Values				
Description	<50% ND M58-O Fluoride	>50% ND M52-UBF Cobalt	100% ND M52-UBF Aluminum	Comments
Results	0.96	<i>0.000125</i>	0.04	Example Values at Each Sampling Event
	0.72	0.00028	0.04	
	0.57	<i>0.000125</i>	0.08	
	0.68	0.00028	0.08	
	0.60	<i>0.000125</i>	0.04	
	<i>0.4</i>	<i>0.000125</i>	0.08	
	<i>0.4</i>	<i>0.000125</i>	0.04	
	<i>0.4</i>	<i>0.000125</i>	0.04	
Number of Samples	8	8	8	
Number of Detections	5	2	0	
Number of Non-Detections	3	6	8	
Percentage of Non-Detect	38%	75%	100%	
Maximum Value Detected	0.96	0.00028	NA	
Method of Handling Non-Detects	Kaplan-Meier	Substitute 50% PQL	Std Dev-10% PQL	
Average Value	0.59	0.00016	0.055	
Standard Deviation	0.18	0.00007	-	
Coefficient of Variation	0.31	0.44	-	StDev/Ave Must be Greater than 0.1
Adjusted Standard Deviation	-	-	0.006	10% of Average
Proposed <i>k</i> Value	9.37	9.37	9.37	UPL with 99% Confidence Level
Calculated UPL	2.32	0.0008	0.11	Sufficiently Protective Against False Positives

Notes:

All results in milligrams per Liter (mg/L).

Red = Values are non-detected at the PQL shown.

UPL = Upper Prediction Limit

Italics = Values have been replaced with half the PQL.

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TABLE 2 - CASE CRITERIA FOR SETTING ALS AND AQLS

PARAMETERS WITH AWQS			
Well Type	Calculated UPL is:	AL	AQL
Case 1 - POC Wells	> 50% non-detects	80% AWQS	AWQS
	< 80% AWQS	80% AWQS	AWQS
	Between 80% and AWQS	UPL	AWQS
	> AWQS	UPL	UPL
PARAMETERS WITH SDWS			
Well Type	Calculated UPL is:	AL	AQL
Case 2 - Supplemental Wells	> 50% non-detects	80% AWQS	None
	< 80% AWQS	80% AWQS	None
	> 80% AWQS	UPL	None
PARAMETERS WITH NO STANDARDS			
Well Type	Calculated UPL is:	AL	AQL
All Wells	UPL	UPL	None

TABLE 3 - ANALYTICAL PARAMETERS REQUIRING AL/AQL CALCULATIONS

Analyte	AWQS	SDWS	AL Method ¹
Common Ions			
Fluoride	4	2	80% AWQS
Magnesium	NE	NE	Well by Well
Sulfate	NE	250	Well by Well
TDS	NE	500	Well by Well
Trace Metals			
Aluminum	NE	0.2	80% SDWS
Antimony	0.006	NE	80% AWQS
Arsenic ²	0.01	NE	80% AWQS
Barium	2	NE	80% AWQS
Beryllium	0.004	NE	80% AWQS
Cadmium	0.005	NE	80% AWQS
Chromium	0.1	NE	80% AWQS
Cobalt	NE	NE	Highest Calculated AL
Copper	NE	1	80% SDWS
Iron	NE	0.3	Highest Calculated AL
Lead	0.05	NE	80% AWQS
Manganese	NE	0.05	Highest Calculated AL
Mercury	0.002	NE	80% AWQS
Nickel	0.1	NE	Highest Calculated AL
Selenium	0.05	NE	80% AWQS
Thallium	0.002	NE	80% AWQS
Zinc	NE	5	80% SDWS ⁴
Organics			
Benzene	0.005	NE	80% AWQS
Ethylbenzene	0.7	NE	80% AWQS
Toluene	1	NE	80% AWQS
Xylene	10	NE	80% AWQS
Radiochemicals			
Alpha ³	15	NE	Highest Calculated AL
Radium 226+228	5	NE	Highest Calculated AL ⁴

Notes:

- 1) The Alert Level Method is estimated based on preliminary data and subject to change.
- 2) MCL Value for arsenic is used per the permit.
- 3) The AWQS applies to Adjusted Alpha which equals Gross Alpha minus Uranium Isotopes. Adjusted Alpha is calculated if Gross Alpha is greater than 12 picocuries per liter, otherwise Gross Alpha is used.
- 4) In all cases, if individual well results are significantly different from the average, a separate AL will be set for the well, while the remaining wells may follow the described method.